NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

November 19, 2018

POWERPLANT GROUP CHAIRMAN'S FACTUAL REPORT

NTSB No: ERA18MA099

A. ACCIDENT

Location:	New York, New York
Date:	March 11, 2018
Time:	1908 EDT
Aircraft:	Airbus AS350B2, Registration Number N350LH

B. POWERPLANTS GROUP

Group Chairman:	Harald Reichel National Transportation Safety Board Washington, DC
Member:	Bryan Larimore Safran Helicopter Engines USA Grande Prairie, Texas

C. SUMMARY

C.1 Accident Summary

On March11, 2018, about 1908 eastern daylight time, an Airbus Helicopters AS-350 B2, registration number N350LH, operated by Liberty Helicopters Inc. under the provisions of Title14 *Code of Federal Regulations* Part 91, was substantially damaged when it impacted the waters of the East River in New York, New York, and rolled inverted, after the pilot reported a loss of engine power in flight, and subsequently entered an autorotation. The pilot sustained minor injuries and the five passengers were fatally injured. Visual meteorological conditions prevailed, and no flight plan was filed for the scheduled 30-minute aerial photography flight which departed from Helo Kearny Heliport (65NJ), Kearny, New Jersey.

The helicopter was in the water for about 18 hours before it was recovered. During the time it was in the water, the engine was in an inverted state. After the water recovery, the helicopter was transported to the New York Police Department (NYPD) Aviation Unit facility at 50 Aviation Blvd., Brooklyn, New York where it remained outdoors under a tarpaulin during a snowstorm for one night. The next morning, it was moved from its transport low-boy onto a hangar transport dolly and placed into the NYPD Aviation Unit hangar, where the powerplant team met between March 12 - 14, 2018 to perform the on-scene field examination of the major engine components.

The fuel control unit (FCU); however, could not be disassembled and examined on-scene, so it was wrapped with absorbent material, in a plastic bag and boxed for temporary storage at the Anglin Aircraft Recovery Services in Clayton, Delaware. It was transferred to the Safran Helicopter Engines facilities in Grande Prairie, Texas, before the powerplant team met on May 2, 2018 for the examination.

The investigation did not find any anomalies with the engine, components or FCU that would have precluded normal operation.

D. DETAILS OF THE EXAMINATION

D.1 Engine Information

D.1.1 Engine History

The accident engine was a Safran HE (formerly known as Turbomeca) Arriel 1D1 Turbine, serial number (S/N) 19549, manufactured in January 2013. The engine was last overhauled in September 22, 2016, at which time, it had accumulated 3599 hours, time since new (TSN). At the time of the event, it had accumulated 1437.1 hours, time since overhaul (TSO) for a TSN of 5,036.1 hours. The power turbine (Nf) total cycles were 5,723.2 and the gas generator turbines (Ng) cycles were 7,228. A review of the Liberty Helicopters logbooks indicated that the last 100-hour engine inspection occurred on

March 6, 2018 at a TSN of 5024.5 hours. The last compressor wash was performed on March 8, 2018.

D.1.2 Engine Description

The event engine, a Safran HE Arriel 1D1 Turbine (Figure 1) is a 2-spool turbo-shaft engine which produces a takeoff power[1] of 531 kilowatts (KW) and has a maximum continuous power[2] rating of 466 KW. A single stage power turbine (PT) drives the output shaft through a 3-stage reduction gearbox (N2). The gas generator (GG) is composed of a compressor section, which has single stage axial, and single stage centrifugal compressors driven by a 2 stage high-pressure axial turbine. The combustion chamber is an annular type featuring centrifugal fuel injection. The engine power management system consists of a fuel pump, which supplies the correct fuel pressure as well as filters the fuel, and a hydro-mechanical FCU, which governs the gas generator (N1) speed to maintain a rotor speed (N2) of 100%. Two input splines in the FCU take RPM input from the GG and the PT shafts.

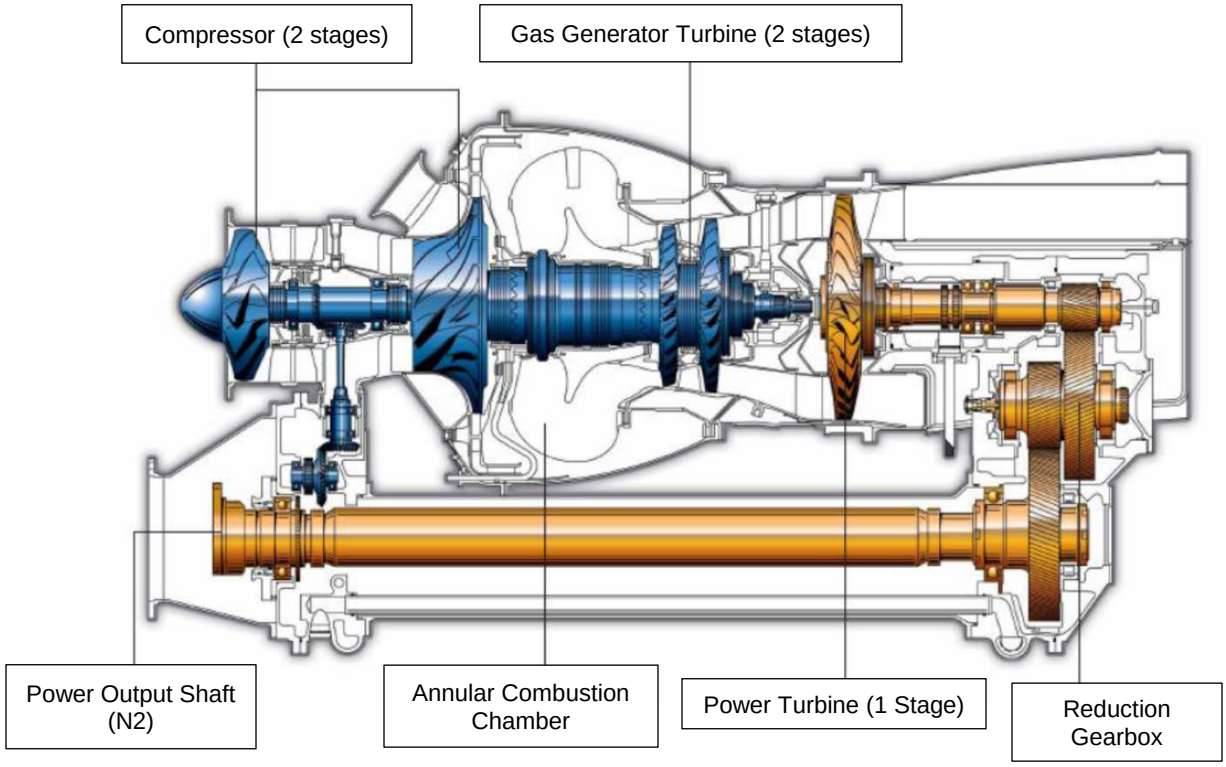


Figure 1 – Safran Turbomeca Arriel 1D1 Engine Cross Section

[1] Takeoff power is the approved brake horsepower that is developed statically under standard sea level conditions, within the engine operating limitations established under Part 33, and limited in use to periods of not over 5 minutes for takeoff operation.
[2] Maximum continuous power is the approved brake horsepower that is developed statically or in flight in standard atmosphere at a specified altitude, within the engine operating limitations established under Part 33, and approved for unrestricted periods of use.

D.2 Details of the Engine Examination

D.2.1 General External Condition

The engine cowling was intact[3] (Photo 1). After the helicopter was in the hangar, the cowling was removed (Photo 2), revealing the engine was still attached to the engine mounts of the helicopter and a clean engine and engine bay. There were no signs of oil or fuel leaks, fire or un-containment. The exhaust duct was intact and undamaged. The air inlet duct was mildly corroded, consistent with being in contact with salt water. The rear engine mounts and the front engine mount flange were intact and undamaged. All the airframe fuel, oil and pneumatic tubes, control cables, linkages and electrical wires and connectors were present and intact. There was mild surface corrosion on some electrical connectors, consistent with salt water contact. An air pressure port at the compressor discharge stage sends a pressure signal to the diaphragms of the acceleration and deceleration control units in the FCU via a P2 tube. A leak in the P2 tube 'b'- nut fittings will result in an engine that will not accelerate. The 'b'- nuts on both ends of the P2 tube were properly torqued. The starter/generator was in its normal location on the accessory gearbox.

The PT wheel was accessed through the exhaust duct and could be rotated with normal effort, but only in the free-wheeling direction, which is consistent with internal gearbox mechanical continuity as well as an intact and operating rotor clutch. The trailing edges of the PT blades were examined through the exhaust duct and were all present and undamaged (Photo 3). The GG spool was accessed by reaching into the air inlet duct and turning the axial compressor wheel. The GG spool could be rotated easily by hand; however, a faint scratching noise could be heard from the core, consistent with corrosion due to salt water contact on the shaft bearings. Because of the possibility that the main shaft bearings could be corroded, it was decided that a safe test cell run could not be accomplished at the factory, so instead, a field strip the engine at the hangar was performed.

D.2.2 Fluids, Filters & Chip Detectors

There are two manual and two electric magnetic (mag) oil chip detectors. The manual chip detectors monitor the oil from module 1 accessory gearbox (AGB) and module 5 reduction gearbox (RGB), while the electric mag plugs respectively monitor the oil from the oil tank and the rear bearing. The manual mag plugs were removed and found to be clean (Photo 4 & Photo 5). The check valves on the mag plug orifices were depressed, which allowed oil to flow from the internal cavity, and a mixture of water and oil was seen to drain. The two electric mag plugs were also examined and found to be clean.

[3] For the purposes of this report, the word intact is used only to indicate that the part/component/assembly is complete and not lacking any part that properly belongs to it.

The Arriel 1D1 engine is a dry sump engine, requiring a separate oil tank, which is remotely installed and the AS350B2 installation has the oil tank mounted on the right[4] side of the transmission deck. The oil level in the tank was just above the minimum level (Photo 6). The oil filter bypass indicator was not triggered indicating no blockage in the oil filter (Photo 7).

The fuel supply line from the firewall to the fuel pump (Photo 8) was disconnected at the firewall fitting and fuel was observed to drain from the line. Several ounces were noted to have drained.

D.3 Engine On-Scene Strip

D.3.1 General

Prior to removal of the engine, all airframe-related fittings and electrical connections were checked for integrity as they were being removed and no discrepancies were found. The engine was then hoisted from the helicopter with an overhead crane and placed on an engine stand (Photo 9) in preparation of a field strip. The transmission input shaft spline was undamaged (Photo 10). The engine bay was generally clean and undamaged (Photo 11). The engine is comprised of 5 modules (Figure 2) and are listed below in order of removal.

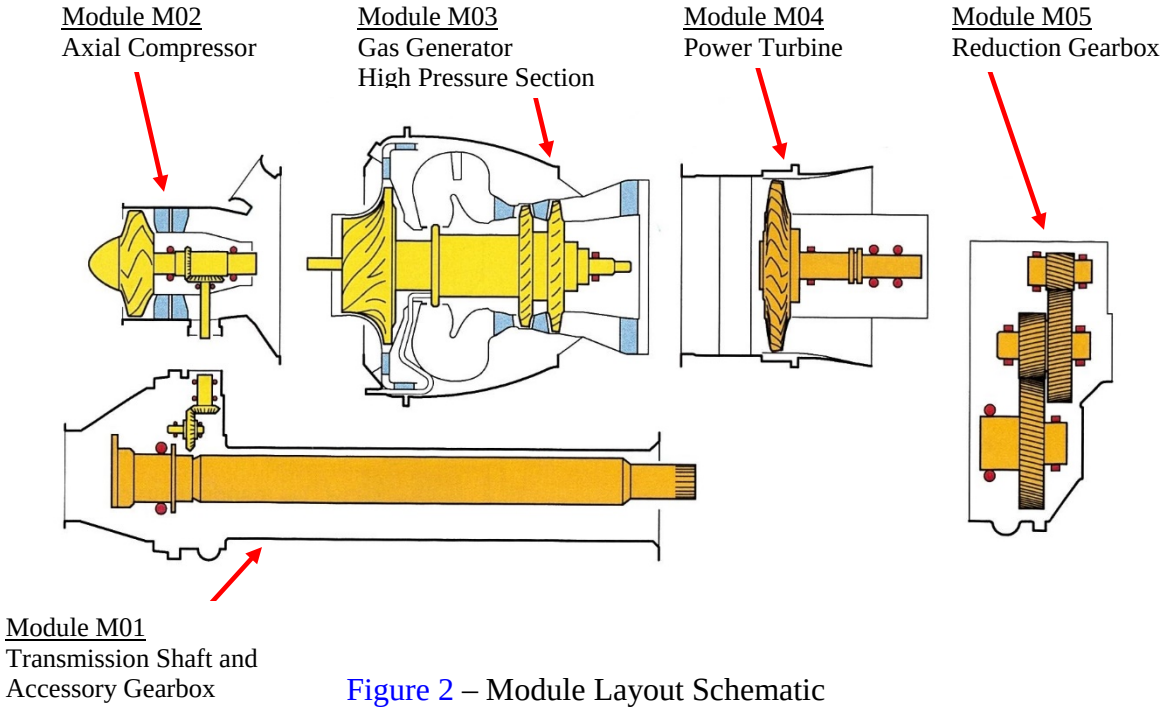


Figure 2 – Module Layout Schematic

[4] All directional references to front and rear, right and left, top and bottom, and clockwise and counterclockwise are made aft looking forward (ALF) as is the convention, unless indicated otherwise.

D.3.2 Module 05 – Reduction Gearbox (RGB)

The engine-related external lines and electrical connectors were checked for integrity as they were being removed and no discrepancies were noted. The tail rotor drive flange was intact and undamaged (Photo 12). Module 05 (RGB) was removed with no difficulties (Photo 13). The input shaft could be rotated smoothly with normal effort and a corresponding rotation of the output shaft was observed, consistent with internal integrity of the reduction gearbox. The input and output splines were intact and undamaged. The input pinion alignment mark was found aligned (Photo 14), consistent with an engine that had not sustained a sudden stoppage while under power.

D.3.3 Module 04 – Power Turbine

Module 04 (power turbine) was removed, revealing intact and undamaged leading edges and pressure side chords of the power turbine blades (Photo 15). The power turbine ball bearings (Photo 16) were oil wetted and could be easily rotated by hand.

The power turbine nozzle guide vanes were undamaged (Photo 17). The GG rear bearing was oil wetted, undamaged (Photo 18) and could be smoothly rotated by hand with normal effort.

D.3.4 Module 02 – Axial Compressor & Module 3 - Gas Generator HP Section

The module 02 (axial compressor) and module 03 (GG) assemblies were not separated but were removed as a unit from module 01 (AGB). The GG spool could be rotated by hand with minimum effort, consistent with undamaged GG spool bearings. The 2nd stage GG turbine was intact and undamaged (Photo 19). The 1st stage axial compressor could be examined, and it was intact and undamaged (Photo 20). The centrifugal compressor and the1st stage GG turbine could not be examined because the field strip tooling could not disassemble the module.

D.3.5 Module 01 – Transmission Shaft and Accessory Gearbox

Continuity of the AGB internal gear train was confirmed through the gearbox which included the bevel gears and accessory drive shafts (Photo 21). The FCU part number (P/N) 0164850960, S/N 1587 was removed from the module 01 with no difficulty. It was shipped to the Turbomeca facilities in Grande Prairie, Texas where it was disassembled and examined. The N2 input to the FCU continuity was confirmed. The FCU output splines for N1 and N2 were intact and undamaged (Photo 22). The freewheel shaft spline was intact and undamaged (Photo 23). The freewheel clutch assembly (Photo 24) was intact and could be rotated in both directions and the proper freewheel and drive operation was confirmed.

D.4 Fuel Control Unit Examination

D.4.1 General

The FCU was wrapped in a plastic bag and shipped in a cardboard box from the Anglin Aircraft Recovery Services in Clayton, Delaware and stored in a secure locker at Safran Turbomeca (Photo 25).

D.4.2 FCU History

The FCU was P/N 0164850960 and S/N 1582. It was overhauled at Safran Turbomeca in April 2016. In October 2016, with zero TSO, it was installed in N452LH, and on July 2017, with 337.5 hours TSO, it was removed from N452LH and installed in N350LH. At the time of the accident, the FCU had accumulated 1043.8 hours TSO.

D.4.3 FCU Description

The FCU supplies fuel pressure, filters the fuel and meters the correct quantity of fuel to the engine for it to start, operate in steady, accelerating and decelerating conditions and shut down.

The major elements of the FCU are (Ref: Figure 3):

1- Fuel pump (FP): a positive displacement gear-type pump with a pressure relief valve.
2- Fuel filter is a metal mesh type filter and is located at the pump outlet. It has a clogged filter by-pass valve.
3- Pressure reducing valve, a diaphragm valve that decreases the pump pressure to supply the control hydraulic system.
4- Manual control valve, a flow control which is used for the engine start and shutdown and for manual over-ride control if there is an automatic control failure. The control lever drives a valve and a metering valve cam.
5- Speed governor for the free turbine (N2 of Nf): a proportional-type governor which features:
    a. a speed detector (flyweight driven by the free turbine).
    b. a datum unit (anticipator cam linked to the collective pitch).
    c. an amplifier piston (potentiometer jet, piston, datum lever and adjustments).
6- Speed governor for the gas generator (N1 or Ng) which features:
    a. a speed detector (flyweight driven by the gas generator)
    b. a pressure modulation device (lever, potentiometer jet)
    c. a temperature compensation device
    d. a damping device (piston and variable jet).
7- Acceleration control unit, which is a capsule-type control unit featuring:

a. An acceleration limiter (capsule to which the P2 air pressure compressor outlet is applied and a lever mechanism in the metering unit).

8- Fuel metering device featuring:

a. a working piston (controlled by the modulated pressure of the fuel control unit)
b. a metering valve (metering needle \which moves in a diaphragm)
c. a constant delta-P valve (diaphragm to which the fuel pressure difference is applied, and which controls a metering valve)

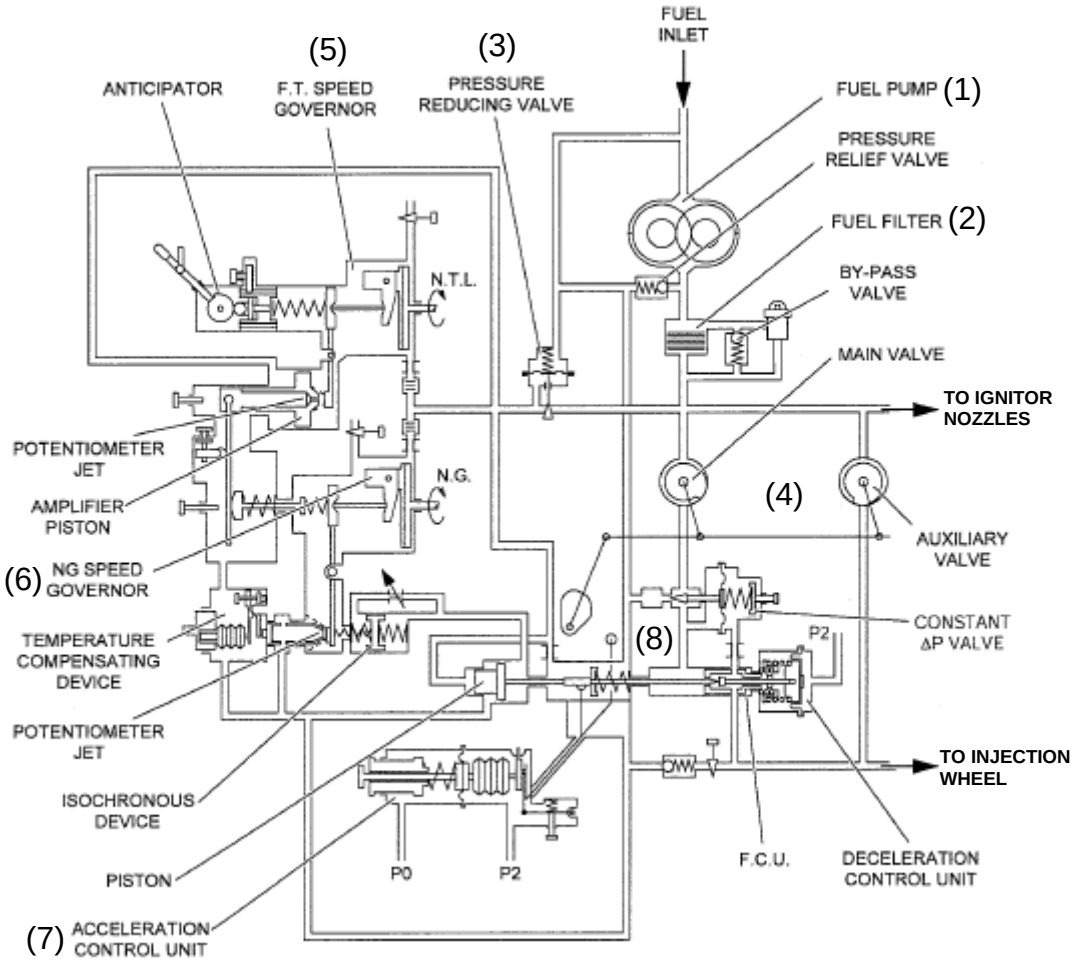


Figure 3 – FCU Schematic

D.4.4 Details of the FCU Examination

D.4.4.1 General External Condition

The FCU was intact and generally clean. An examination of the plastic bag in which the FCU was stored for the previous three weeks, revealed that approximately an ounce of water that had drained from the FCU.

The FCU was secured to a factory bench support (Photo 26) and examined. Most of the external screw head surfaces were mildly corroded, consistent with salt water contact. An examination of the open P2 fitting revealed the presence of an orange colored liquid.

All the anti-tamper lock-wire seals were original, in place and intact, indicating that all the settings of the FCU were factory standard. Both the throttle and anticipator (collective) input levers could be rotated with normal effort.

Throughout the disassembly, the seals and o-rings were examined, and no anomalies were noted on any rubber sealing component.

The fuel inlet port was wetted with fuel.

D.4.4.2 FCU Teardown

The acceleration controller section was removed, revealing a cavity that contained a paste-like substance, consistent with a water/grease mixture after a water inundation (Photo 27). The deceleration controller section was removed and was found to be clean (Photo 28).

The temperature compensator was removed and found to be clean (Photo 29).

When the anticipator cavity cover was removed, a mixture of fuel and water drained from the cavity (Photo 30); however, the anticipator cavity was free of corrosion (Photo 31). The internal helix and worm gears were clean, intact and undamaged.

The FCU core housing was removed and was intact. It was generally clean, except for the acceleration controller cavity, previously noted (Photo 32).

The slope stop assembly was removed, revealing internal cams and mechanisms that were coated with a grease/water slurry; however, all the mechanisms moved smoothly and without effort. Additionally, the cam surfaces were clean and undamaged beneath the grease/water paste (Photo 33).

The intermediate body was removed (Photo 34), revealing clean and undamaged Ng and Nf flyweight mechanisms (Photo 35) that moved smoothly, an intact P-rod link,

and a clean and undamaged main metering valve (Photo 36). The Nf flyweight shaft was corroded; however, the Nf flyweight seal was undamaged and the shaft bearing rotated smoothly (Photo 37).

The fuel filter was removed, examined and found to be clean (Photo 38).

The working piston assembly and sleeve were intact, undamaged and clean (Photo 39). The amplifier piston assembly and sleeve were intact, undamaged and clean (Photo 40).

The fuel pump section was disassembled, revealing intact shafts, bearings, gear teeth and side seals (Photo 41). The input shaft spline was intact and there was slight corrosion between the spline and bearing surface.

The delta P diaphragm assembly was disassembled and found to be clean, intact and undamaged. The rubber diaphragm was intact, undamaged and still pliable (Photo 42).

D.5 Engine restart attempt

The pilot stated that after the loss of power event, he attempted to relight the engine[5] and indicated he had obtained a relight and initial startup of the engine, but it had not yet reached a power condition before the helicopter contacted the water. The helicopter was equipped with an Appareo unit, which is an image recording device mounted above and just aft of the pilot's seat and can record the instrument panel and helicopter control actions. An attempt to read and recover image data from the Appareo unit was unsuccessful and it was determined that the unit was not operational. The lack of image recording data precluded the analysis of the relight attempt. For additional information see the FOQA image recorder factual report.

Harald Reichel
Aerospace Engineer – Powerplants

[5] See pilot's statement reference

Photo 1 - Safran Turbomeca Arriel 1D1 Engine In-Situ on N350LH

Photo 2 – N350lH Engine Cowling Raised

Photo 3 – Power Turbine Blades – Undamaged

Photo 4 – Manual Magnetic Chip Plug from Module 01 (AGB) - Clean

Photo 5 – Manual Magnetic Chip Plug from Module 05 (RGB) - Clean

Photo 6 – Engine Oil Tank – On Transmission Deck

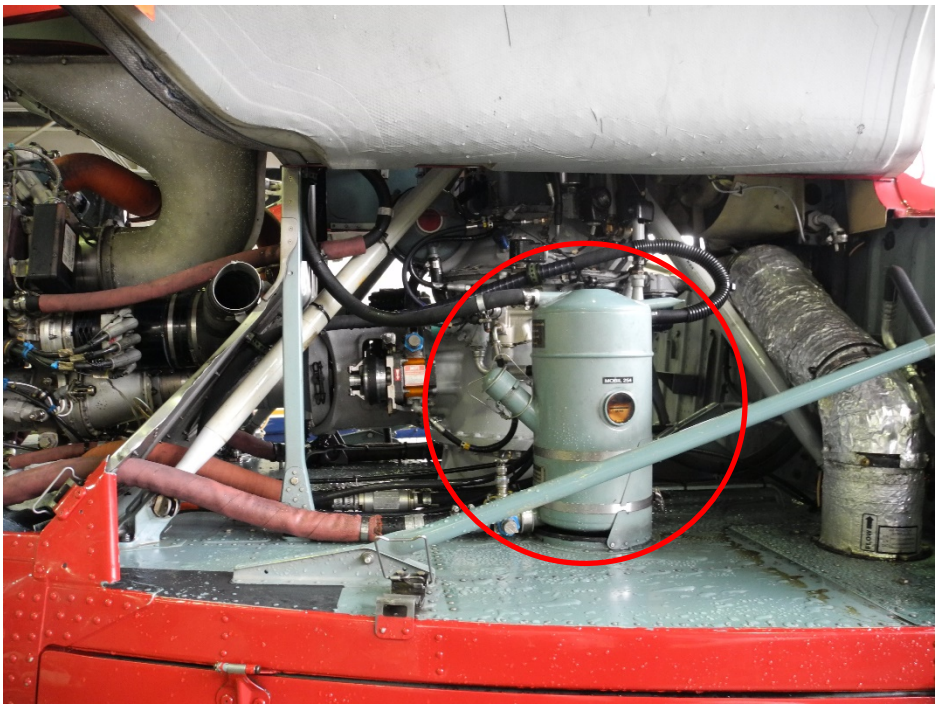


Photo 7 – Engine Oil Filter Bypass Indicator – Not Triggered

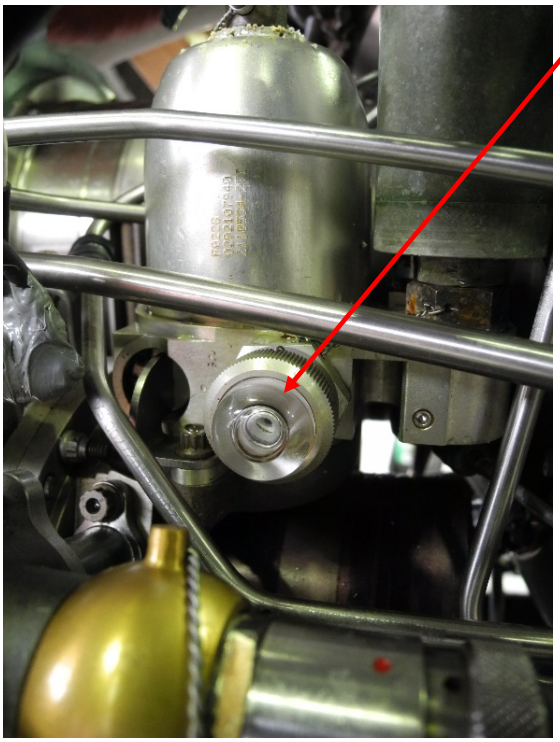
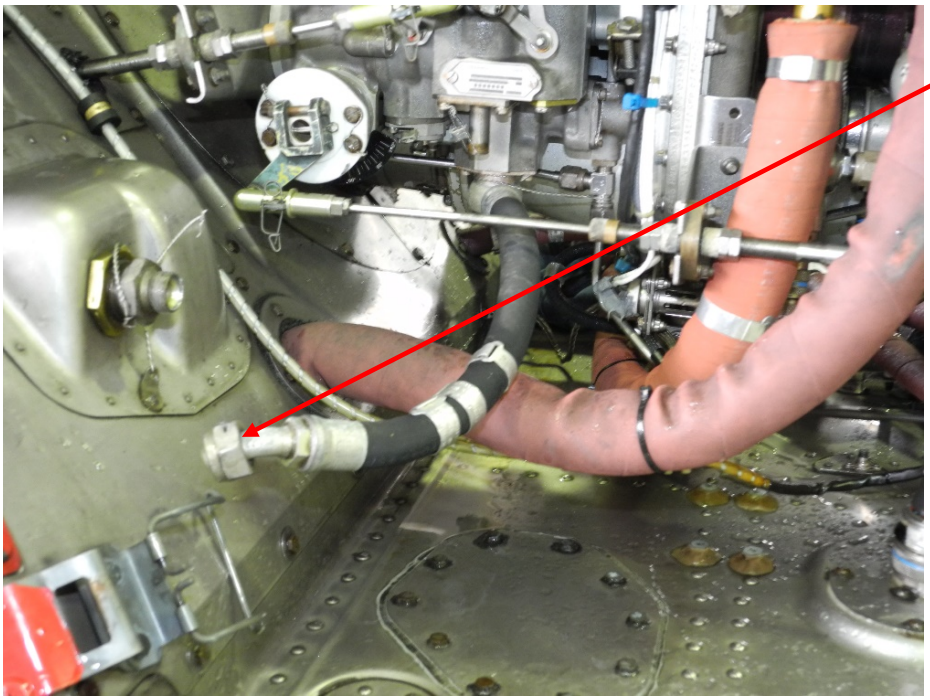


Photo 8 – Fuel Supply Line from the Firewall to the HP Pump (in FCU)



Fuel Supply Line has been Disconnected from the Firewall Fitting

Photo 9 – Engine Removed from the Helicopter

Photo 10 – Transmission Input Shaft Spline - Undamaged

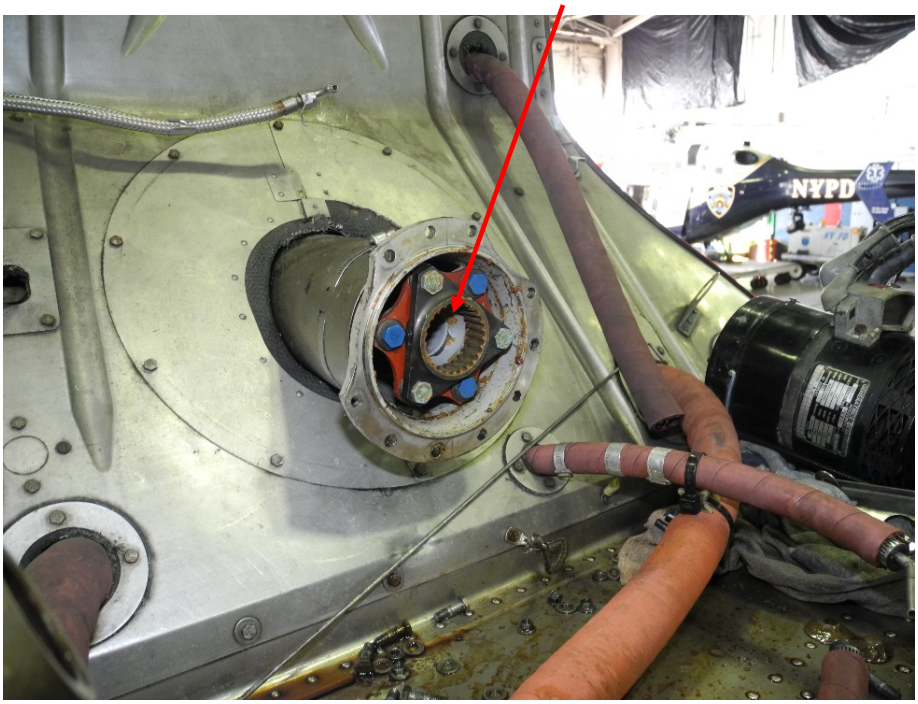


Photo 11 – Engine Bay After Removal of Engine – Undamaged

Photo 12 - Tail Rotor Drive Flange - Undamaged

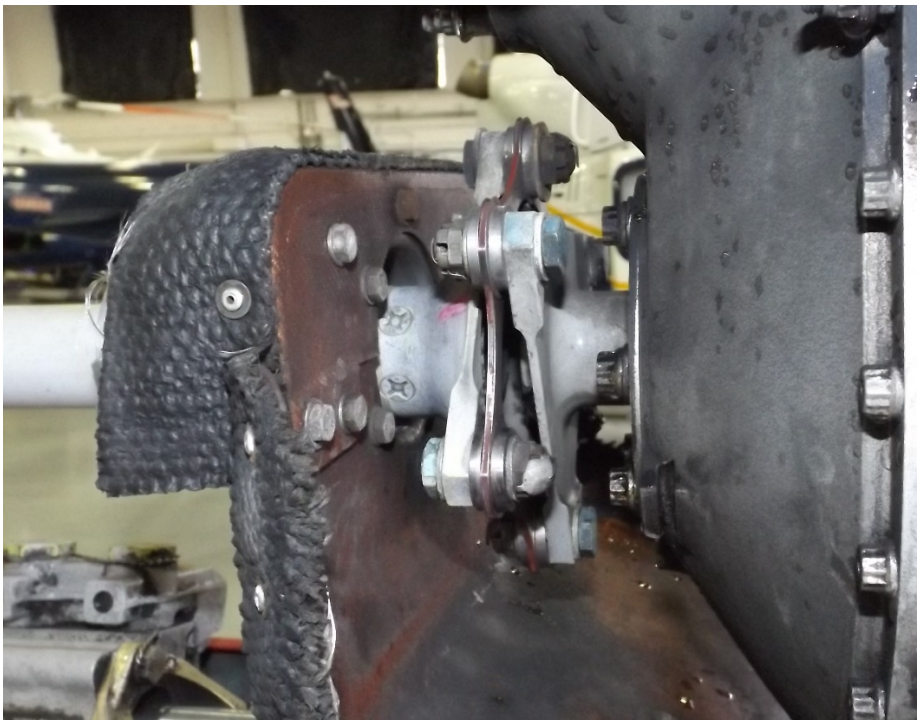


Photo 13 – Module 05 – RGB – Intact & Undamaged

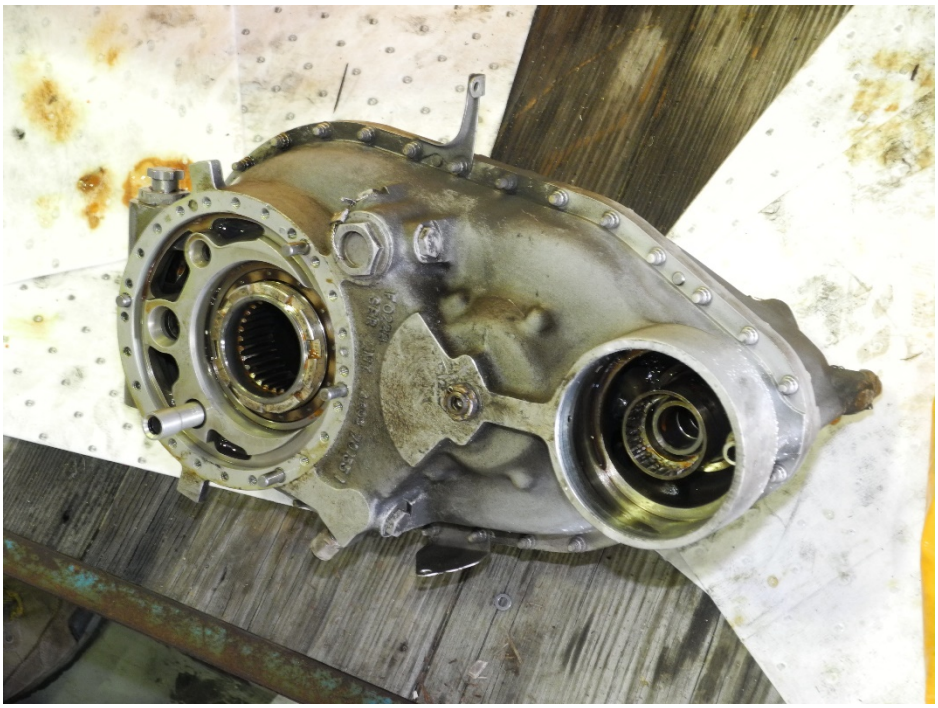


Photo 14 – Input Pinion Alignment Marks – Still Aligned

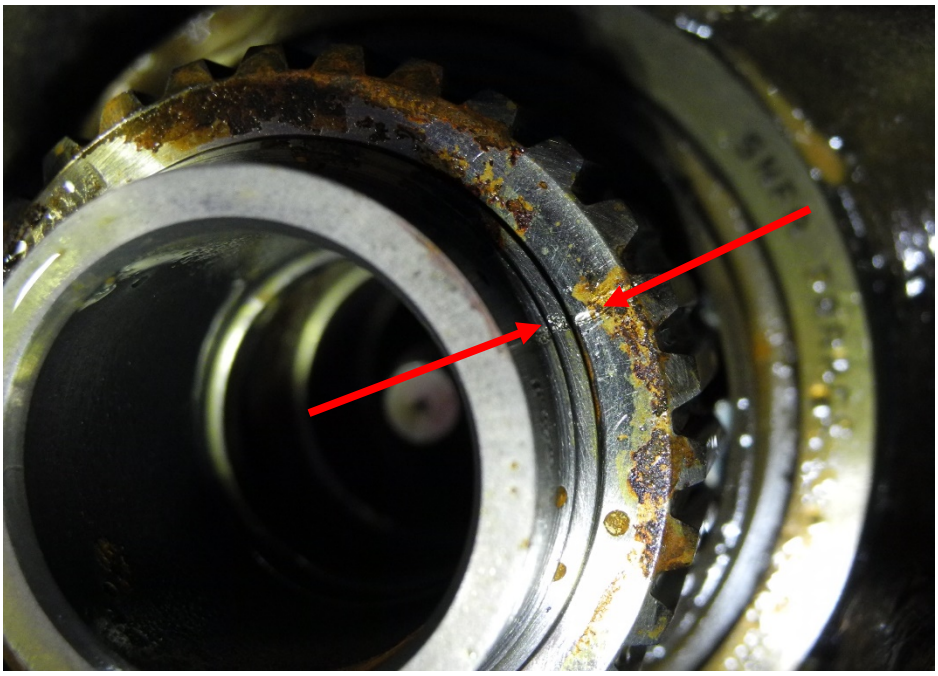
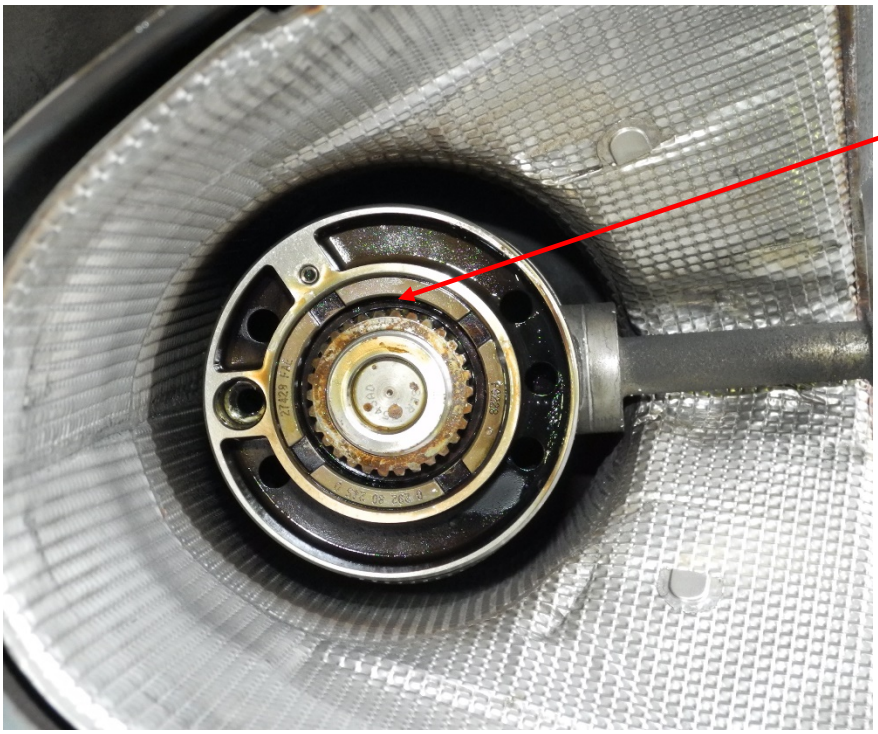


Photo 15 – Power Turbine Blades – Leading Edges and Pressure Side Chords - Undamaged

Photo 16 – Power Turbine Aft Bearing - Undamaged



Roller Elements are Intact and Oil Wetted

Photo 17 - Power Turbine Nozzle Guide Vane – Trailing Edges - Undamaged

Photo 18 - GG Rear Bearing - Undamaged

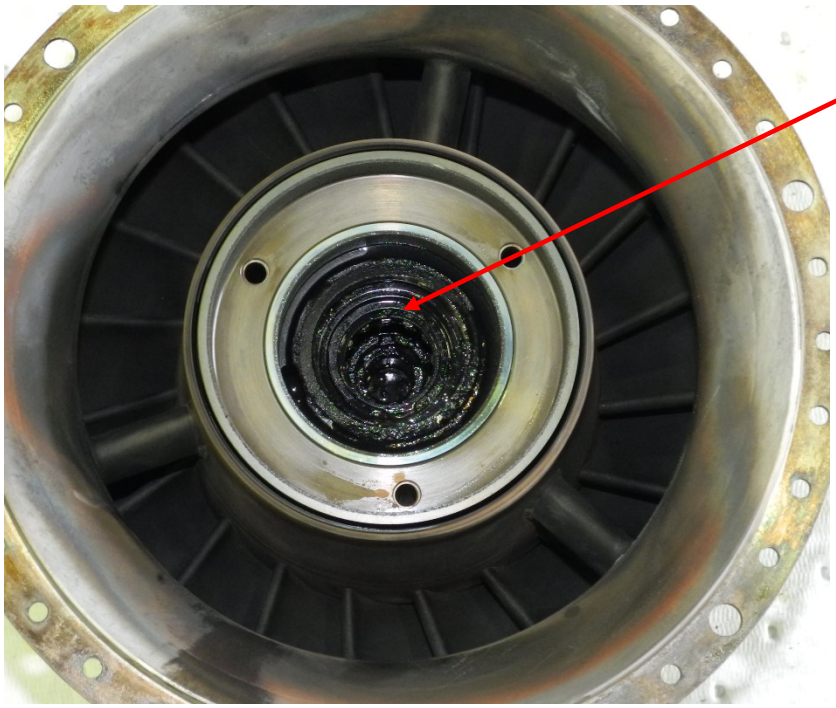


Photo 19 - 2nd Stage GG Turbine - Undamaged

Photo 20 – 1st Stage Compressor Wheel - Undamaged

Photo 21 - Bevel Gear Input Spline - Undamaged

Photo 22 – AGB N1 & N2 Output Splines for FCU - Undamaged

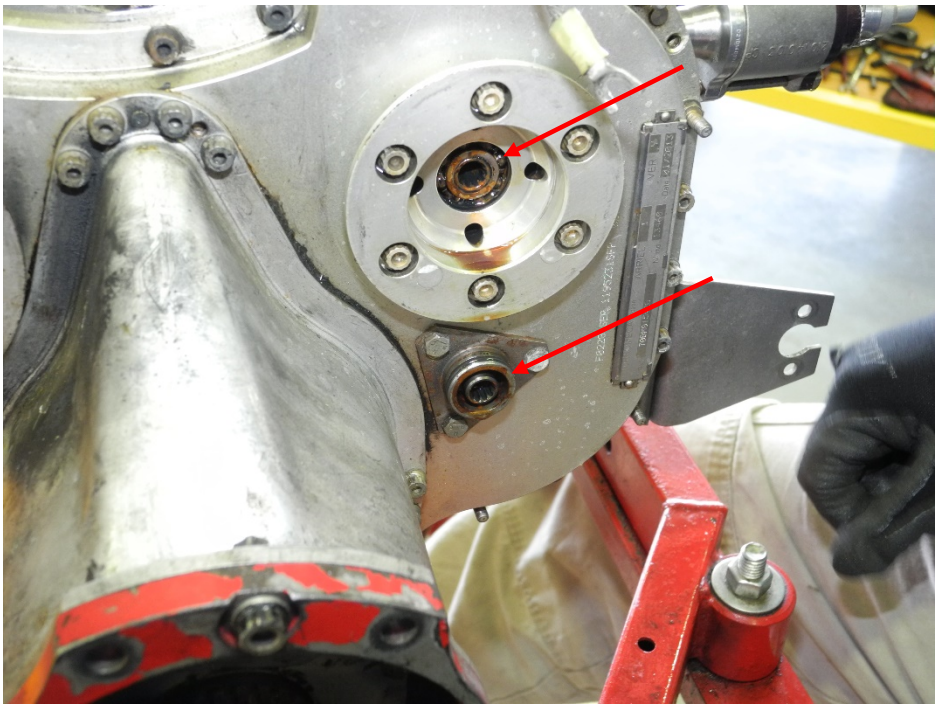


Photo 23 - Freewheel Shaft Spline - Undamaged

Photo 24 – Freewheel Clutch Assembly - Undamaged

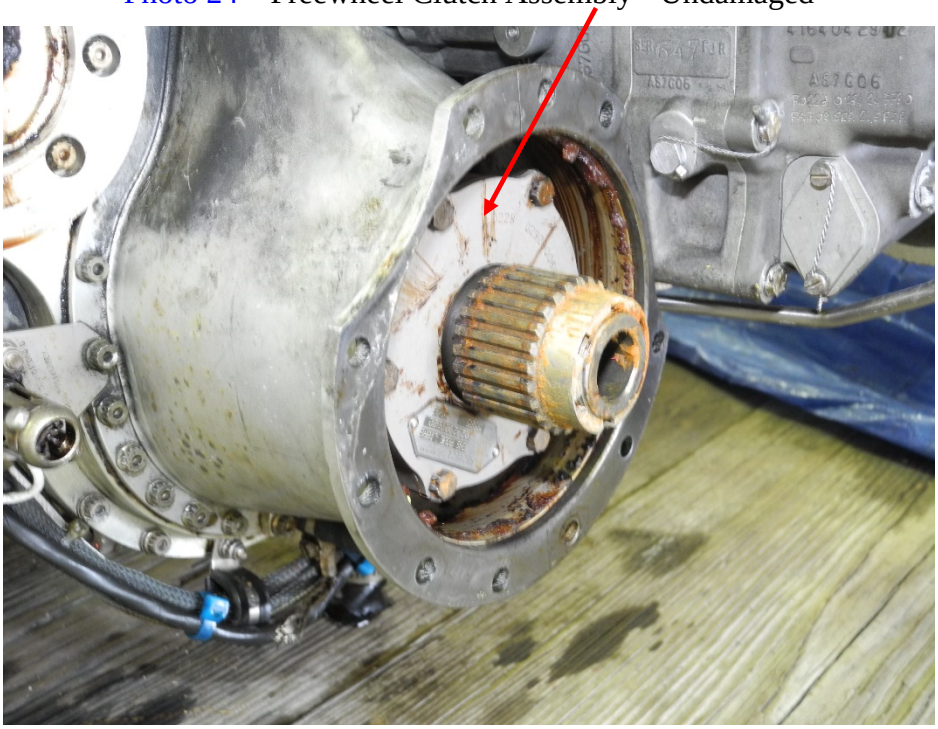


Photo 25 – FCU - As Received at SAFRAN Factory

Photo 26 – FCU in Factory Support Fixture

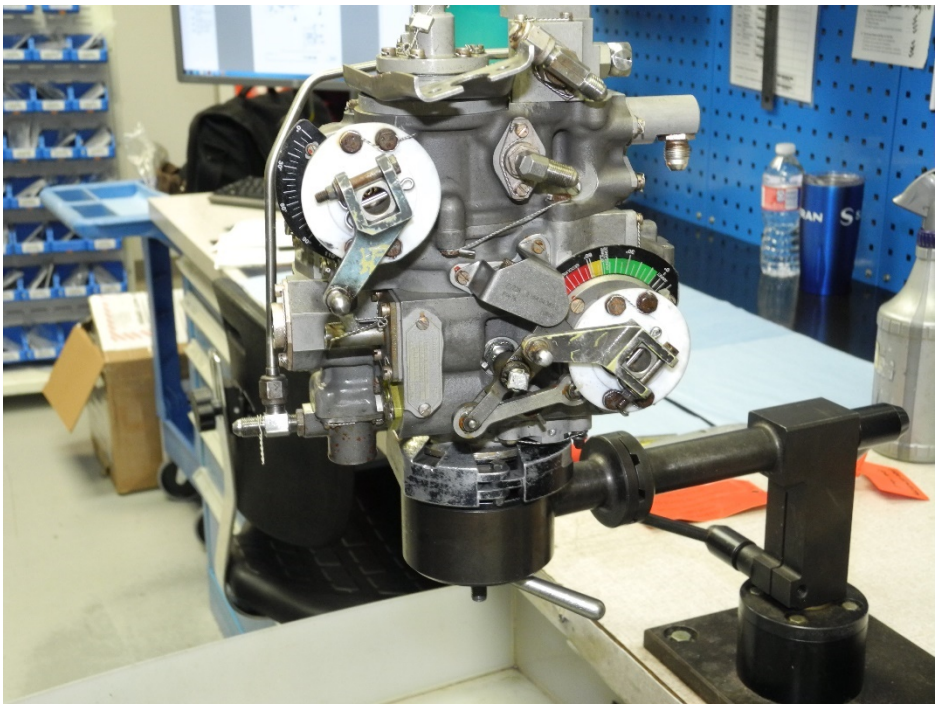


Photo 27 – Acceleration Controller Cavity – Water/Grease Mixture

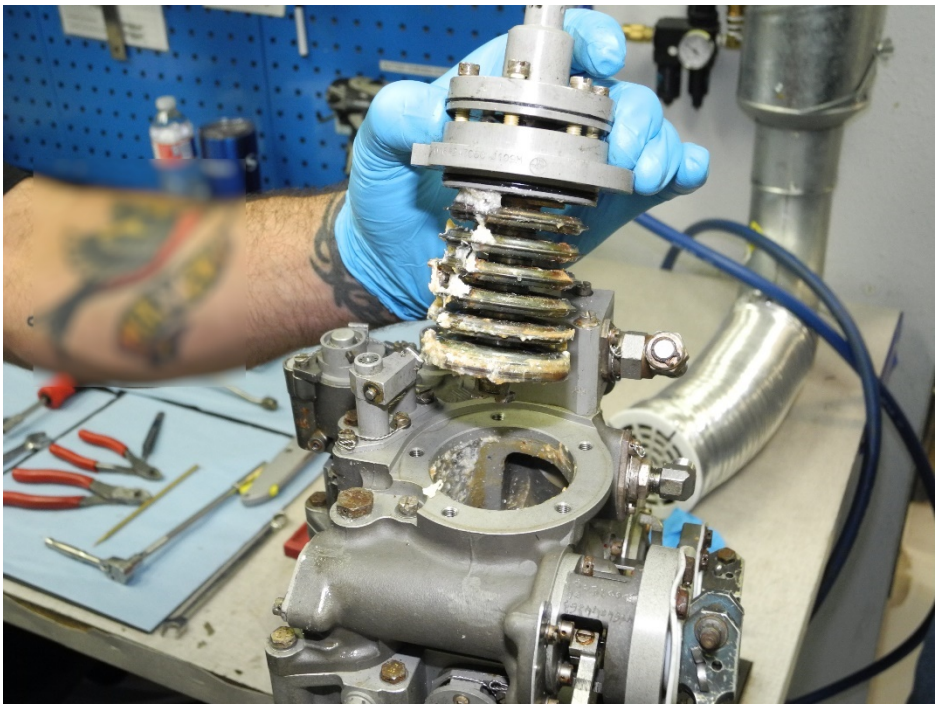


Photo 28 – Deceleration Controller - Clean

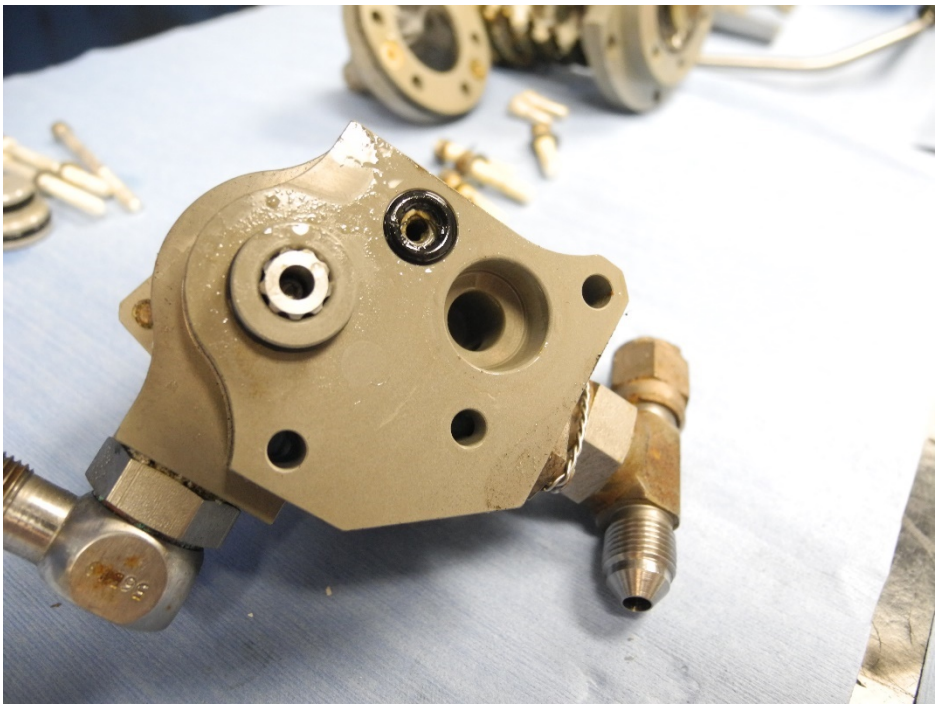


Photo 29 – Temperature Compensator - Clean

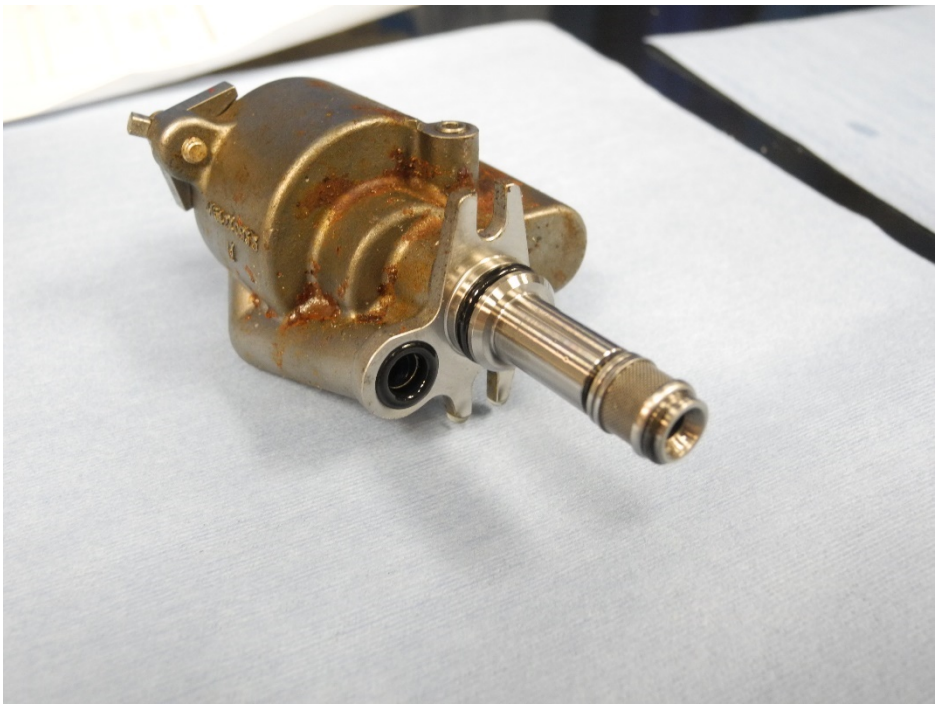


Photo 30 – Water/Fuel Mixture Drained from Anticipator Cavity

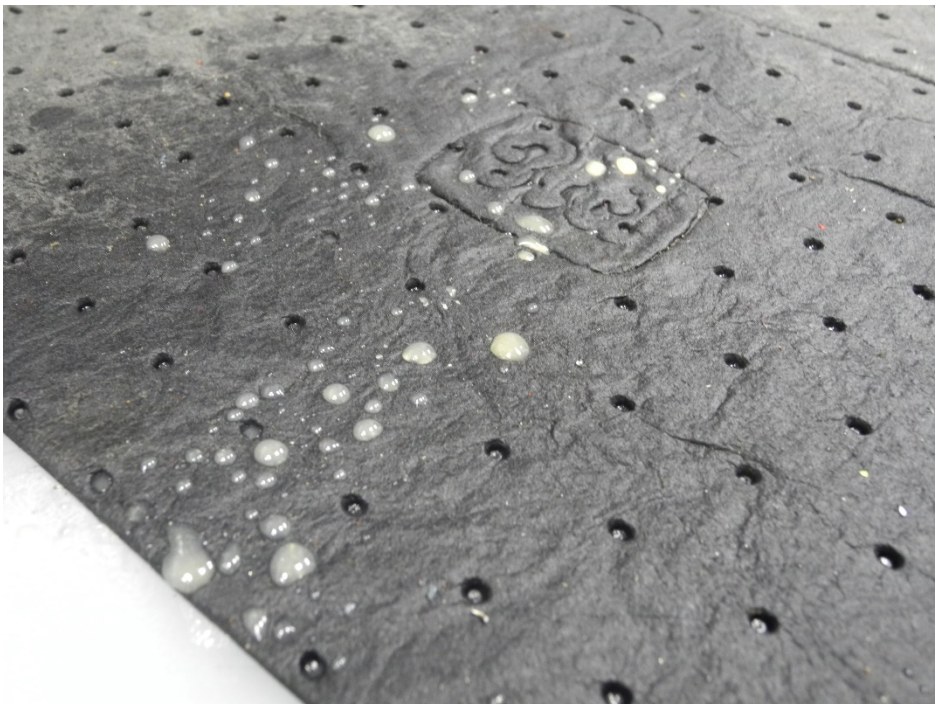


Photo 31 – Anticipator Cavity - Clean

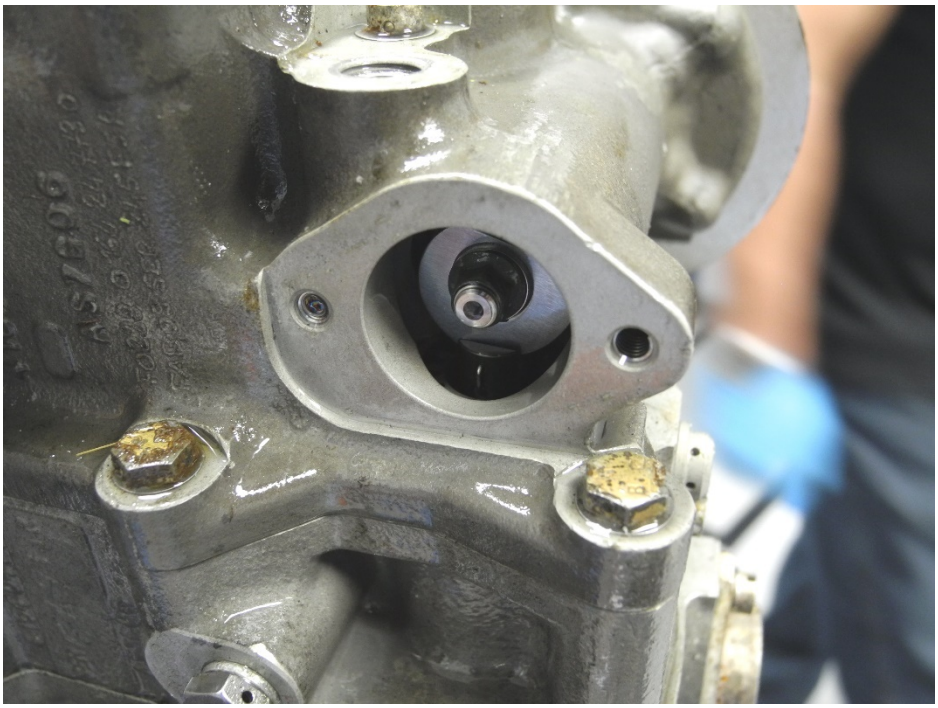
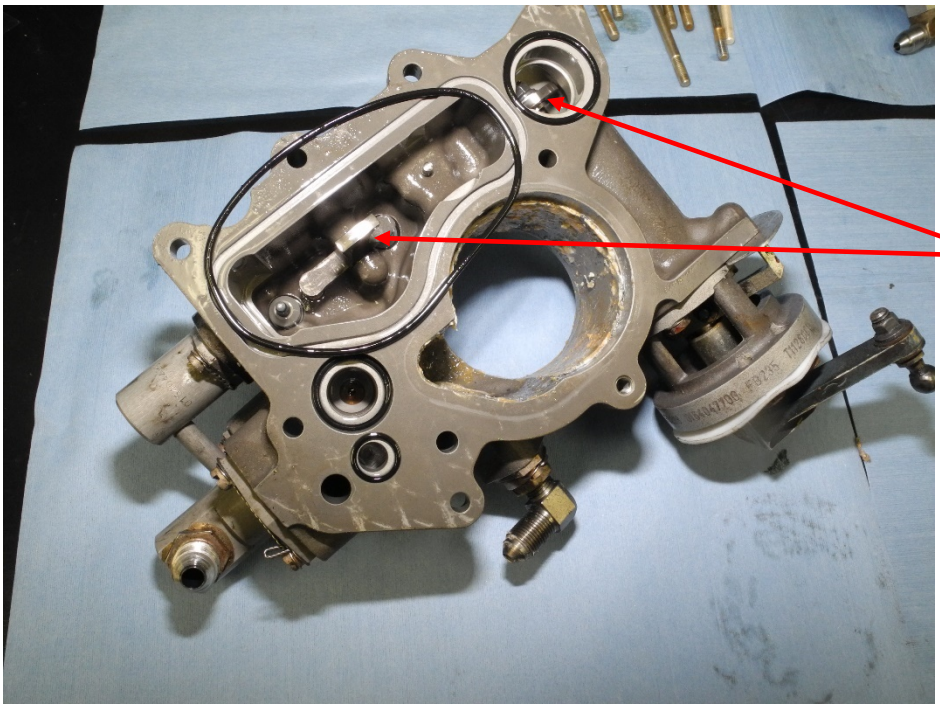


Photo 32 – FCU Core Assembly – Intact and Undamaged



Cam Faces – Clean and Undamaged

Photo 33 – Slope Stop Assembly - Undamaged

Photo 34 – Removal of Intermediate Body of FCU

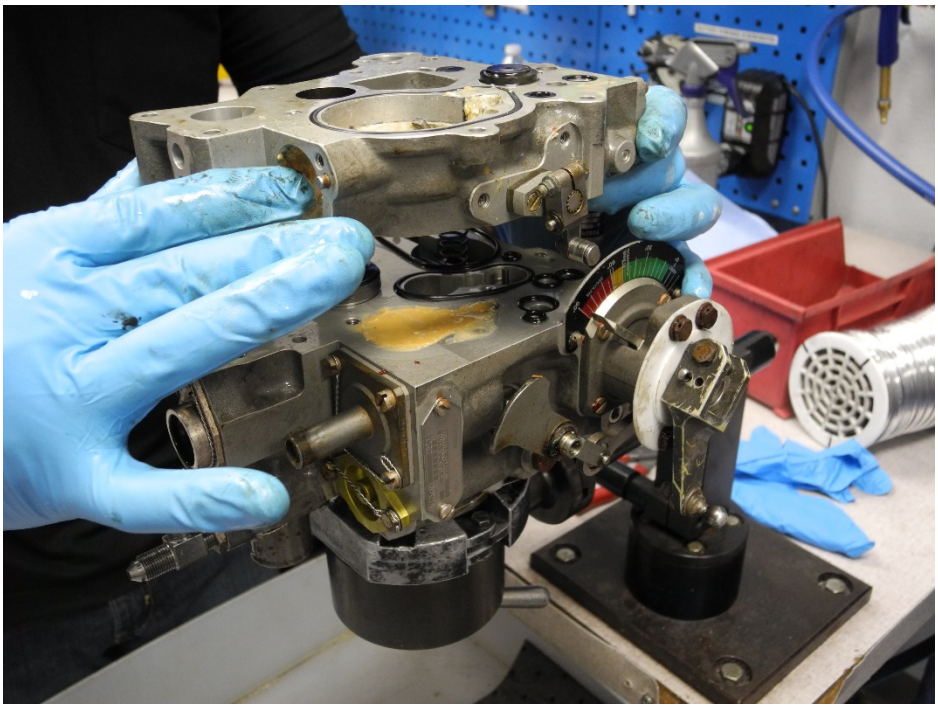


Photo 35 – Ng and Np Flyweights – Clean and Undamaged

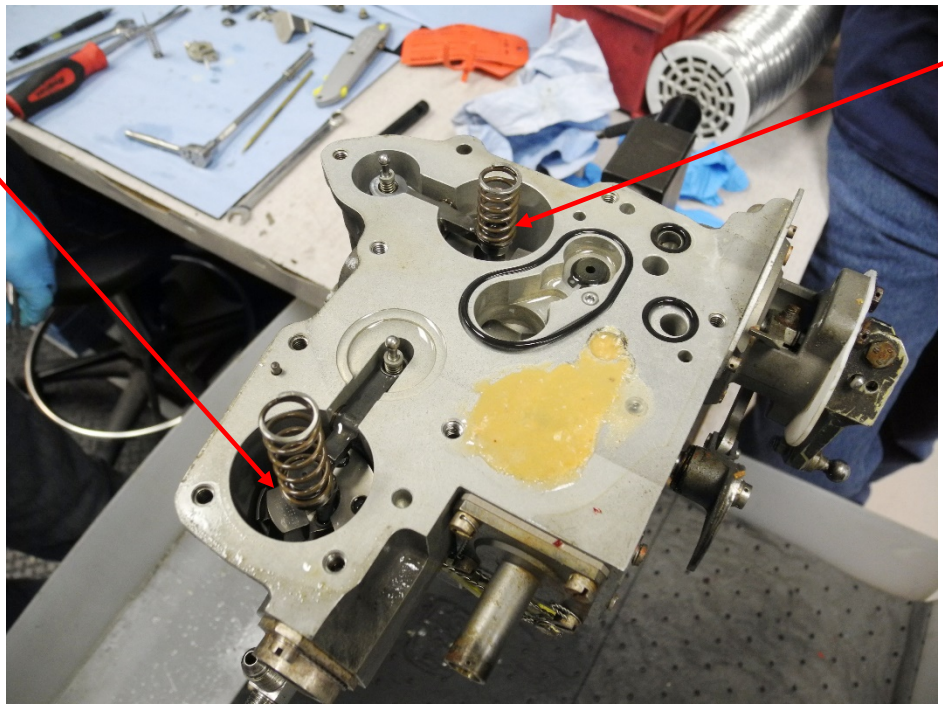


Photo 36 – Main Metering Valve – Clean and Undamaged

Photo 37 – Nf & Ng Flyweight Assemblies - Undamaged

Photo 38 – Fuel Filter - Clean

Photo 39 – Working Piston & Sleeve - Undamaged

Working Piston Sleeve - Undamaged

Working Piston

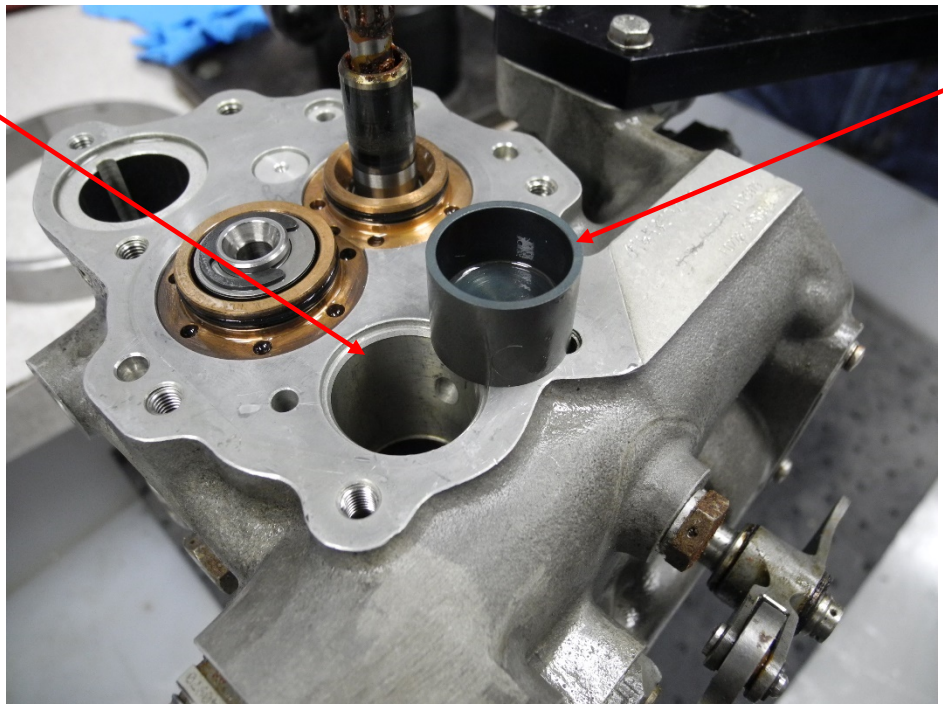


Photo 40 – Amplifier Piston Assembly & Sleeve - Undamaged

Amplifier Piston & Sleeve

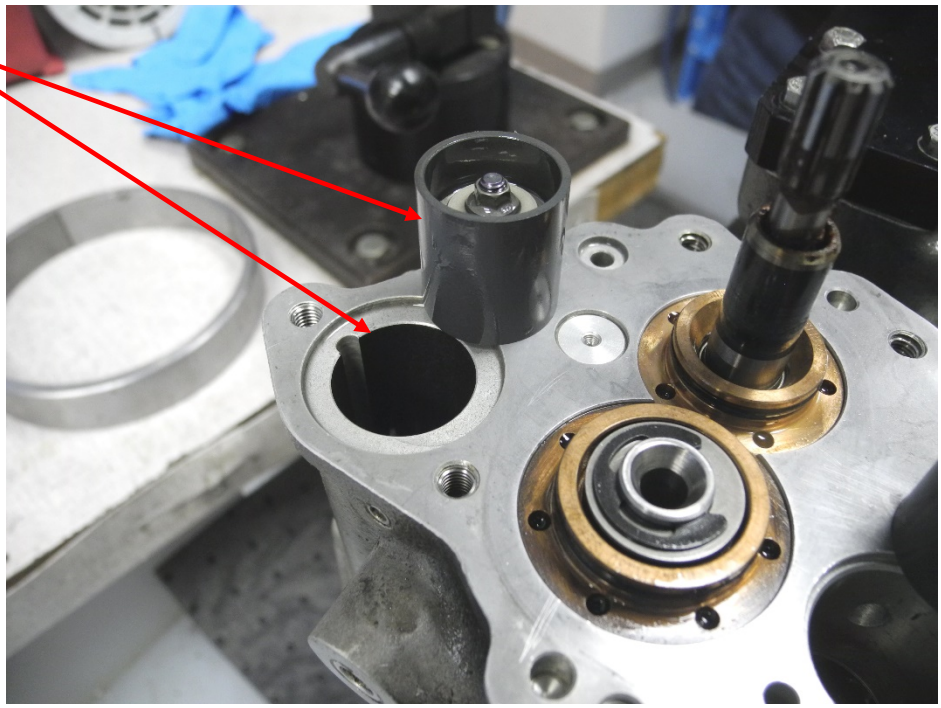


Photo 41 – Fuel Pump Gears & Side Seals - Undamaged

Photo 42 – Delta P Diaphragm Assembly - Undamaged